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ASIAN DEVELOPMENT BANK

ENERGY EFFICIENCY SUPPORT PROJECT

SECTOR ANALYSIS
FERTILIZER INDUSTRY

SUPPORTED BY
GOVERNMENTS OF THE NETHERLANDS AND INDIA

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PREPARED BY

TATA ENERGY RESEARCH INSTITUTE, NEW DELHI

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Executive summary

The Government of Netherlands (through the Asian Development Bank) and the Government of India has jointly launched a project entitled 'Energy Efficiency Support Project (ESP)' to look into various aspects of energy and environmental issues pertaining to the Indian industry. The project comprises of two distinct phases. Phase-I of the project deals with identification of industry sectors where there is a substantial scope for energy saving and pollution reduction through energy efficiency investments. Phase-II of the project primarily covers various initiatives like undertaking energy and environmental audits, feasibility studies, training programmes and promotional campaigns for industry sectors identified under the phase-I of the study. One of the sectors covered for detailed analysis by TERI under phase-I is the fertiliser sector.

Agriculture has been the mainstay of the Indian economy from the very beginning. Since the prospects of increasing the arable land are almost exhausted, the country has to depend on increasing the grain yield/hectare. One of the most important inputs required to achieve this is by the use of chemical fertilisers. During the last two decades, the growth of the Indian fertiliser industry has been spectacular and today, India ranks fourth in the world in fertliser production. In the present report, an assessment is carried out with respect to the performance of the Indian fertiliser industry, with special emphasis on energy and environmental issues. In order to provide a focussed discussion, only ammonia-urea plants are covered under the assessment. Urea was selected primarily because; (i) the manufacture of urea is most energy intensive amongst various fertiliser products and (ii) urea production accounts for 80% of the total nitrogen production in our country.

The fertiliser industry is one of the largest consumer of hydrocarbon energy. It is estimated that manufacture, packing, transport and application of 1 kg of nitrogen fertiliser requires about 2 kgs of fossil fuel. Nitrogen production capacity uses naphtha, natural gas, fuel oil and coal as feedstock. Natural gas with 45.7% share and naphtha with 28.4% share are the dominant feedstocks. Fuel oil and coal have 14.2% and 5.2% share respectively. 51% of the investment in all nitrogenous fertilisers is in the public sector companies. Ammonia is the major intermediate for production of nitrogenous and complex fertilisers. Production of ammonia constitutes major part of energy consumption in production of fertiliser products. More than 80% of energy required in production of urea is spent in ammonia production.

The performance of fertiliser plants from energy viewpoint has shown a steady improvement over the years as can be gauged from the fact that the specific energy consumption for ammonia production has progressively reduced from 14.8 Gcal in 1979-80 to 11.4 Gcal in 1992-93. The present specific energy consumption for the urea varies between 5.79 Gcal for the most efficiently running plant to 13.0 Gcal for the most inefficient one. The absolute energy consumption by this sector has been estimated at 112 Gcal. This includes the energy requirement for the fuel and the feed. It has been estimated that the total energy saving potential in the sector is 10% of the total energy use.

Many technological gaps exist in old as well as new fertiliser plants. Various revamp/retrofit options are available to modernise these plants. Some of the major energy saving options for both ammonia and urea plants are; (i) reformer tubes of superior material, (ii) adiabatic pre-reformer for steam reforming, (iii) reduction of steam/carbon ratio, (iv) purge gas recovery unit in ammonia synthesis, (v) ammonia synthesis converter revamp, (vi) installation of urea hydrolyser stripper and (vii) use of internal heat recovery system in urea plant. Latest material of construction, better heat recovery, lower steam/carbon ratio, etc. are available to modernise reforming section of ammonia plants. Similarly, better solvents and promoters, better tower packing, use of hydraulic turbine for energy recovery, etc. offer good opportunities for energy consumption reduction in CO_2 recovery section. Synthesis converter revamp, molecular sieve drying, more active catalyst, purge gas recovery are some of the options for improving energy efficiency in ammonia plants. Use of better designed reactor with internal heat recovery and installation of urea hydrolyser stripper offer opportunities for both material and energy savings in urea plants.

Fertiliser plants are highly polluting in nature. But the industry has taken positive steps to control and minimise the release of pollutants. As of June, 1994, all the plants were found to comply with the emission standards laid down by pollution control boards. However, further scope still exists in reducing ammonia loss specially in old plants.

The performance of the industry (except for the sick units in the public sector) is quite impressive with some units achieving better specific energy consumption levels compared to design norms. However, it is recommended that appropriate provisions should be made in the retention pricing scheme (RPS) to further encourage investment in energy conservation projects. In the early phase of the RPS for fertiliser, normative consumption of various inputs was taken into account. This encouraged the improvement in energy efficiency over and above the norms. In addition, there were special fiscal incentives for implementing energy conservation measures. These schemes need to be reinstated to encourage fertiliser plants to further improve the efficiency of energy use.

Based on the assessment of this sector and its comparative evaluation with other sectors covered under Phase-I of this ADB Energy Efficiency Support Project, Fertiliser sector is recommended for Phase-II of ESP.

CHAPTER 1

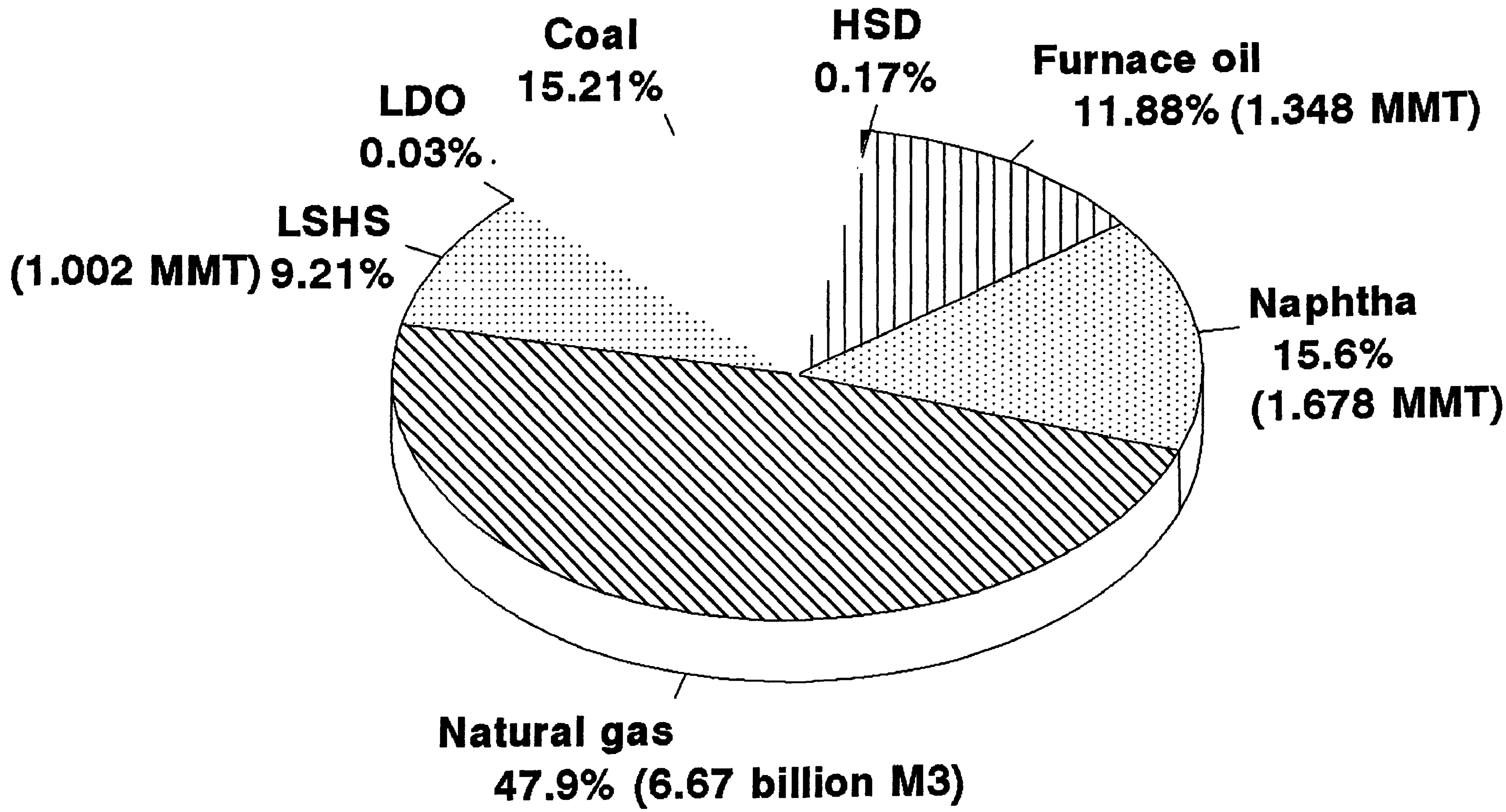
Introduction

Agriculture is the main stay of Indian economy from the very beginning. Its contribution to GDP is still substantial and stands at 33%. With no let up in the growth of the population in the country, agricultural sector shall continue to dominate the Indian economy scene. Since the prospects of increasing the arable land are almost exhausted, the country has to depend on increasing the grain yield per hectare. One of the most important inputs required to achieve this is by use of chemical fertilizers.

During the last two decades, the growth of Indian Fertilizer Industry has been spectacular and has kept pace with global technological development. The discovery and exploitation of large associated/natural gas reserves in Bombay High/Basin offshore fields gave a major impetus to the development of the industry. However, fertilizer plants are capital, technology and energy intensive and require long gestation period. The scarce capital resources and raw material shortages raise serious doubts on any significant capacity addition in future. The fertilizer industry (nitrogenous fertilizer in particular) is highly energy intensive. It is estimated that manufacturing, packing, transport and application of 1 kg of nitrogenous fertilizer requires about 2 kg of fossil fuel. Any effort, therefore, to conserve material or energy would result in substantial savings, reduced energy costs and will reduce burden of petroleum products import. In view of the liberalised economic environment, the need to concentrate efforts on containing energy wastages and increasing productivity has also become imperative. Though the recent large gas based ammonia-urea plants have been operating very successfully at optimum specific energy consumption levels, yet there exists certain areas where further improvements could be possible.

Fertilizer industry is one of the largest consumer of hydrocarbon energy. Petroleum products play a vital role in fertilizer production, where they are used both as raw material and as fuel. The absolute quantity of different forms of energy consumed by the industry and their relative share for the year 1992-93 is shown in **figure 1**.

Fig.1: Share of Fuels Consumed in Fertiliser Industry



Base year: 1992-93

Note: HSD consumption - 18,000 MT, LDO consumption - 3,000 MT
Coal consumption - 4 MMT

In the present report, an assessment is carried out with respect to the performance of the Indian fertilizer industry with special emphasis on energy and environmental issues. In order to provide a focused discussion, only ammonia-urea plants are covered under the assessment. This is done primarily because (i) the manufacture of urea is most energy intensive amongst various fertilizer products and (ii) urea production accounts for about 80% of the total nitrogenous fertilizer production in our country. Various issues discussed in this report are related to the technology status od the Indian industry, energy use pattern, environmental implications, the various energy saving opportunities at a macro level and other related issues. Plant specific data for ten industrial units are also included in the report as per the TOR (Terms of Reference) of the study.

CHAPTER 2

Industry sector profile

2.1 Growth of the industry

The nitrogenous fertilizer industry has come a long way since 1951. Prior to this, the only form of nitrogenous fertilizer production was a small amount of ammonium sulphate generated as a by product. The commissioning of Sindri fertilizers in 1952 marked the beginning of a major initiative for the production of nitrogenous fertilizers. During the decade 1951-61 two fertilizer producing facilities were established, one each at Nangal and Varanasi. During the decade 1961-71, the sector witnessed a remarkable growth with the commissioning of several plants. Since then there has been continuous growth in number of fertilizer plants based on various feed stocks and process routes. At present 54 nitrogenous and complex fertilizer plants are in operation in the country and four plants are in the pipeline. India now ranks fourth in the world in fertilizer production with operating capacity of 8.5 million tonnes of nitrogen and 2.8 million tonnes of P_2O_5.

The product pattern has undergone considerable change in the last 40 years of fertilizer production. In fifties, almost all the nitrogenous fertilizer produced was in the form of ammonium sulphate. In late sixties with the commissioning of the Nangal fertilizers and implementation of Rourkela fertilizer plants, Calcium Ammonium Nitrate (CAN) was introduced in the market though a small urea plant was also set up at Sindri. Between 1961-71, urea became the predominant product. Now urea is the main source of nitrogen in India. **Table 1** shows the share of nitrogen nutrient through various products and how it changed from 1951 to 1993-94.

In the initial period, the contribution of private sector of fertilizer production was only marginal. A change in the government policy, however, triggered the interest of private entrepreneurs in this sector resulting in groups like E.I.D. Parry, Sriram, CFL and IEL setting up fertilizer plants. The present ownership pattern (public/private/cooperative), in nutrient production is 51.1%, 30.9% and 18% respectively. Another 12.7% and 87.3% capacity projects are under implementation for public and private sectors respectively.

Table 1. Share of Products in Nitrogen Production (thousand tonnes)

	Nutrients				
Year	AS	CAN	Ammonium Chloride	Urea	Complex
1951-52	100.0	-	-	-	-
1960-61	73.4	9.4	2.3	4.8	1.0
1965-66	38.9	43.4	1.7	5.3	4.6
1970-71	15.2	9.5	0.7	60.6	12.8
1975-76	8.3	10.2	0.3	67.0	13.8
1980-81	4.2	4.0	0.2	71.9	18.7
1985-86	2.5	2.2	0.6	79.5	15.2
1992-93	1.6	1.8	0.4	81.3	14.9
1993-94	1.8	2.3	0.5	83.7	11.7

Note : AS - Ammonium Sulphate
: CAN - Calcium Ammonium Nitrate

2.2 Feedstock & raw materials

During the early stage of fertilizer industry, various feedstocks like firewood, coke, lignite, electrolysis (power), coke oven gas, etc. were utilized for the production of hydrogen for ammonia production. This wide spectrum of feedstock changed gradually with the advent of new process techniques and availability of petroleum based feedstock, viz., naphtha, fuel oil and natural/associated gas.

The technological developments centered around the use of light hydrocarbons included use of new varieties of catalyst incorporating total energy integration concepts coupled with the use of centrifugal compressors or turbines, large size of the plants and improved materials of construction. Along with the technological developments in fertilizer production, there was simultaneous growth in refining capacity in the country. In the seventies, there was apprehension on the prices and availability of naphtha, forcing decision to establish some plants using coal as feedstock (due to its readily availability) and utilizing heavy residual fuel oil available from the refineries. Two plants based on coal and five plants based on Low Sulphur Heavy Stocks (LSHS) fuel oil were commissioned in late seventies and early eighties.

In the later half of the seventies, there were large finds of crude oil, natural/associated gas in the off shore and on shore in the Western and North Eastern parts of the country. It was, therefore, decided to use the associated/natural gas (after separation of higher hydrocarbons) for the production of ammonia. Accordingly, 10-12 plants were approved and established in the country. Utilisation of natural gas together with incorporation of latest technological developments resulted in reducing the energy requirements by about 25-30%. These aspects are discussed in detail in the next chapter.

Thus, it can be observed that the feedstocks for fertilizer production has considerably changed over the years. The dominant position of natural gas as feedstock for ammonia production is obvious from **Table 2,** which shows the share of different fertilizers over a period of last 14 years.

Table 2. Capacity of Nitrogen According to Feedstock

Period	Naphtha	Natural/Ass. gas	Power	Coke oven Gas/others	Lignite	Coal	Fuel Oil	Imported NH_3
1960	-	-	0.80	99.2	-	-	-	-
1965	43.5	-	14.0	30.3	12.2	-	-	-
1970	65.3	10.2	6.0	13.3	5.2	-	-	-
1975	73.2	13.7	3.1	7.3	2.7	-	-	-
1980	51.7	13.0	1.7	1.4	-	9.9	19.6	2.7
1985-86	37.3	30.9	1.2	1.0	-	6.7	17.4	5.5
1990-91	30.5	41.9	-	1.3	-	5.6	14.5	6.2
1993-94	28.4	45.7	-	1.4	-	5.2	14.2	5.1

2.3 Demand and supply scenario

Use of chemical fertilizers in the country has been increasing steadily over the years in concurrence with India's effort to attain self-sufficiency in food grains production. **Table 3** shows consumption of nitrogenous fertilizer nutrients (nitrogen) in absolute terms and its share in all types of fertilizer nutrients (N, P_2O_5, K_2O) over a period of time starting 1951.

Table 3. Consumption of Fertilizer Nutrients (million tonnes)

Year	N	Share in total (%)
1950-51	0.05	78.57
1955-56	0.10	82.44
1960-61	0.21	72.11
1965-66	0.57	73.25
1968-69	1.20	68.65
1973-74	1.82	64.42
1978-79	3.42	66.84
1984-85	5.48	66.81
1989-90	7.38	63.85
1990-91	7.99	62.83
1991-92	8.04	63.21
1992-93	8.42	69.33
1993-94	8.76	71.08
1994-95	9.51	70.35

With this spectacular growth in consumption, production of nitrogenous fertilizers in the country has also increased sharply. The licensed capacity and production since 1951 is shown in **Table 4.**

Table 4. Installed Capacity & Production of Nitrogenous Fertilizers (thousand tonnes)

Year	Installed Capacity	Production (year end)
1951-56	100	76.9
1960-61	121	112.0
1965-66	470	237.9
1966-69	855	563.0
1973-74	1947	1049.9
1978-79	3274	2173.0
1984-85	3902	2224.3
1985-86	5241	3917.3
1989-90	8147	6747.4
1990-91	8147	6993.1
1991-92	8211	7301.5
1992-93	8510	7430.6
1993-94	8594	7231.2
1994-95	8934	7944.0

Comparing tables 3 and 4 it could be observed that demand had always outstripped the in-country production, making imports inevitable. To meet the growing demand, import of fertilizers has risen significantly over the years. **Table 5** shows import of nitrogenous fertilizers and its share in total fertilizer imports.

Table 5. Import of Nitrogenous Fertilizer (thousand tonnes)

Year	Import	Share in total (%)
1983-84	656.1	48.42
1984-85	2008.6	55.41
1985-86	1615.8	48.75
1986-87	1105.6	48.61
1987-88	174.8	17.77
1988-89	218.5	13.53
1989-90	523.1	16.81
1990-91	412.3	14.97
1991-92	566.1	20.39
1992-93	1152.3	38.92
1993-94	1562.6	49.75

To meet the growing demand of urea, significant capacity addition has been planned. **Table 6** gives the projections of urea demand till the year 2000. These projections have been made keeping food grains target in considerations.

Table 6. Urea Demand Projection (million tonnes)

Year	Demand
1997-98	19.99
1998-99	21.31
1999-2000	22.50

Due to strategic reasons, it has been the policy that the gap between demand and supply should be around 1.0 million tonnes of nitrogen.

2.4 Global trends in fertilizer consumption

India ranks 4th in the world in the consumption of fertilizers. The yield of major crops and per hectare fertilizer consumption in India, however, is much lower compared to other countries as can be seen from **Table** 7. The present absolute consumption is likely to go up by about 80% of present consumption level by the turn of the century, if we meet our food grains target of around 245 million tonnes.

Table 7. Fertilizer Consumption and Yield of Major Crops (Kg/hectare)

Country	Fertilizer Consumption	Yield			
		Paddy	Wheat	Maize	Potato
Egypt	343.7	7659	5255	6000	20225
U.S.A.	99.8	6411	2650	8247	35429
Brazil	52.7	2122	1423	2280	14124
China	307	5807	3295	4522	11300
India	75.2	2607	2397	1637	16196
Holland	580.7	-	8015	25000	40869
France	289.2	5193	6494	7887	35866
Former USSR	85.1	3316	1966	2455	11661
World	92.9	3571	2562	3980	14890

2.5 Ammonia production

All the down stream nitrogenous and complex fertilizers are produced through ammonia as an intermediate. Therefore, ammonia remains the single most-largest and most important chemical for the fertilizer industry.

Ammonia (NH_3) is produced by synthesizing nitrogen and hydrogen in molar ratio of 1:3, patented for the first time in the beginning of this century. Since then, this basic concept of synthesis of ammonia has not changed. Except that hydrogen production by electrolysis of water and by calcium cyanamide (now discontinued), all processes utilize carbonaceous fossil fuels for ammonia production. Main process steps using these raw materials consist of following steps:

- Synthesis gas production
- Shift conversion
- Purification of synthesis gas
- Compression and ammonia synthesis

The first step in the manufacturing of ammonia is the production of synthesis gas, which is a mixture of hydrogen and carbon monoxide. Either partial oxidation/gasification of

coal/naphtha/fuel oil/natural gas or reformation of naphtha/natural gas are the major routes for preparing ammonia synthesis gas. To produce more hydrogen and reduce the carbon monoxide content, the synthesis gas passes through a shift conversion reaction. It is further purified to obtain pure hydrogen by the removal of carbon dioxide and carbon monoxide. Nitrogen from air and purified hydrogen react at elevated pressures to produce ammonia.

2.5.1 Synthesis gas production

Ammonia is produced by reacting hydrogen with nitrogen. While nitrogen for the reaction is obtained from atmospheric air, hydrogen can be obtained from several sources, also referred to as feedstocks. Naphtha, fuel oil, natural gas, associated gas, coal and water are the sources form which hydrogen can be produced on a commercial scale. In India, fossil fuel sources like naphtha, fuel oil, coal and natural gas are the principal sources of hydrogen. Fertilizer plants located at integrated shell plants use raw coke oven gas as feedstock. A plant using electricity as feedstock wherein hydrogen is obtained by the electrolysis of water is also in operation.

The major processes for manufacturing synthesis gas form different hydrocarbon feedstocks are:

- Steam reforming
- Partial combustion
- Coal gasification

2.5.1.1 Steam Reforming

The hydrocarbon feedstock (like naphtha) is mixed with steam and heated before being passed through a nickel catalyst bed in a fuel fired furnace called the primary reformer. The temperature in the primary reformer is around 790 °C. The hydrocarbon feedstock gets converted to a mixture of hydrogen, carbon monoxide and carbon dioxide.

The reforming reaction is endothermic and can be represented as following equation:

$$C_n H_{(2n+2)} + nH_2O \rightarrow nCO + (2n+1)H_2; \Delta H = +52 \text{ kcal/mole for } n=1$$
$$= +238 \text{ kcal/mole for } n=6$$

Heat contained in the reformer flue gases is recovered in a waste heat boiler by generation steam. The reaction continues in the secondary reformer where nitrogen in the form of compressed air is added so that eventually a nitrogen to hydrogen ratio of 1:3 on a volume basis is attained. The hot product gases from the secondary reformer (temperature around 930 °C) are cooled by passing them through a waste heat boiler to generate steam or

alternatively preheat the incoming air to the secondary reformer. The gases then enter the shift conversion system.

2.5.1.2 Partial Combustion

This process has the advantage and capability of handling a variety of hydrocarbon feedstocks like gas, crude oil, fuel oil etc. The process can thus be used where light hydrocarbons are unavailable or expensive. It employs a non-catalytic partial combustion of the hydrocarbon feed with oxygen feed with oxygen in the presence of steam in a combustion chamber at flame temperatures between 1300-1500 °C to form carbon oxides and hydrogen. The reaction is exothermic, and for overall efficient operation, heat recovery from the product gas is important. The product gas has a composition that depends upon the carbon-hydrogen ration of the feed and the amount of steam added. The three commercial versions of the process viz., Texaco, Shell and Nontecatini differ primarily in the design and operation of the partial oxidation burner (Austin, 1985).

2.5.1.3 Coal Gasification

Gasification of coal is the first step whenever coal is to be used as a feedstock for production of synthesis gas. Synthesis gas is obtained by reacting coal with steam and oxygen in gasifiers which are of three types - fixed bed, entrained flow and fluidised bed.

2.5.2 Shift conversion

The synthesis gas produced is introduced to a water gas shift reactor where carbon monoxide content is reduced and more hydrogen is produced. Shift conversion is represented by the following reaction:

$$CO + H_2O \xrightarrow{FeO} CO_2 + H_2 \; ; \; \Delta H = -9.806 \text{ kcal/mole}$$

The shift reaction is favoured by low temperature but is carried out in two steps - the high temperature shift conversion and the low temperature shift conversion. The heat released in the shift conversion reactions recovered by generating steam.

2.5.3 Purification of Synthesis Gas

Purification is aimed at removing carbon monoxide and carbon dioxide from the synthesis gas. Carbon dioxide is absorbed in a circulating chemical solution. The absorbed carbon dioxide gas is removed from the solution by means of a stripper. The final stage is

synthesis gas preparation is to remove any traces of carbon monoxide and carbon dioxide. This is accomplished in a methanation unit in which residual carbon oxides are converted to methane in a nickel catalyst bed.

2.5.4 Ammonia Synthesis

The purified synthesis gas containing the right proportion of nitrogen and hydrogen is admitted to a special reaction vessel (converter) at elevated pressures in the presence of a metal oxide catalyst. Smaller plants operating at higher pressure use reciprocating compressors while new and larger plants operating at lower pressure use centrifugal compressors.

The ammonia synthesis reaction is:

$N_2 + 3H_2 \rightarrow 2NH_3$; $\Delta H = -22$ kcal/mole

To maintain the right reaction temperature (338-421 °C), the heat released in the exothermic reaction is extracted by passing the product gas through a waste heat boiler for raising steam. The reaction being exothermic, care must be taken to obtain the optimum temperature which favours both the ammonia equilibrium and rate of reaction. The product gases are then cooled to separate and condense ammonia. The ammonia is stored under pressure, at around 20 atmospheres. Conversion to ammonia being only partial, the unconverted reactants are recycled back to the ammonia converter.

2.6 Urea production

Urea manufacture essentially consists of three steps:

- Ammonia and carbon dioxide are reacted at high pressure (137-341 atmospheres) and temperature (121-182 °C) to form ammonium carbonate and urea solution.
- Ammonium carbonate and urea are separated; ammonium carbonate is decomposed by steam to obtain ammonia and carbon dioxide which is turn are recycled.
- Urea solution is concentrated and pumped in to a drilling tower to obtain urea granules.

Urea production involves two chemical reactions. The first reaction is exothermic where ammonium carbonate is formed.

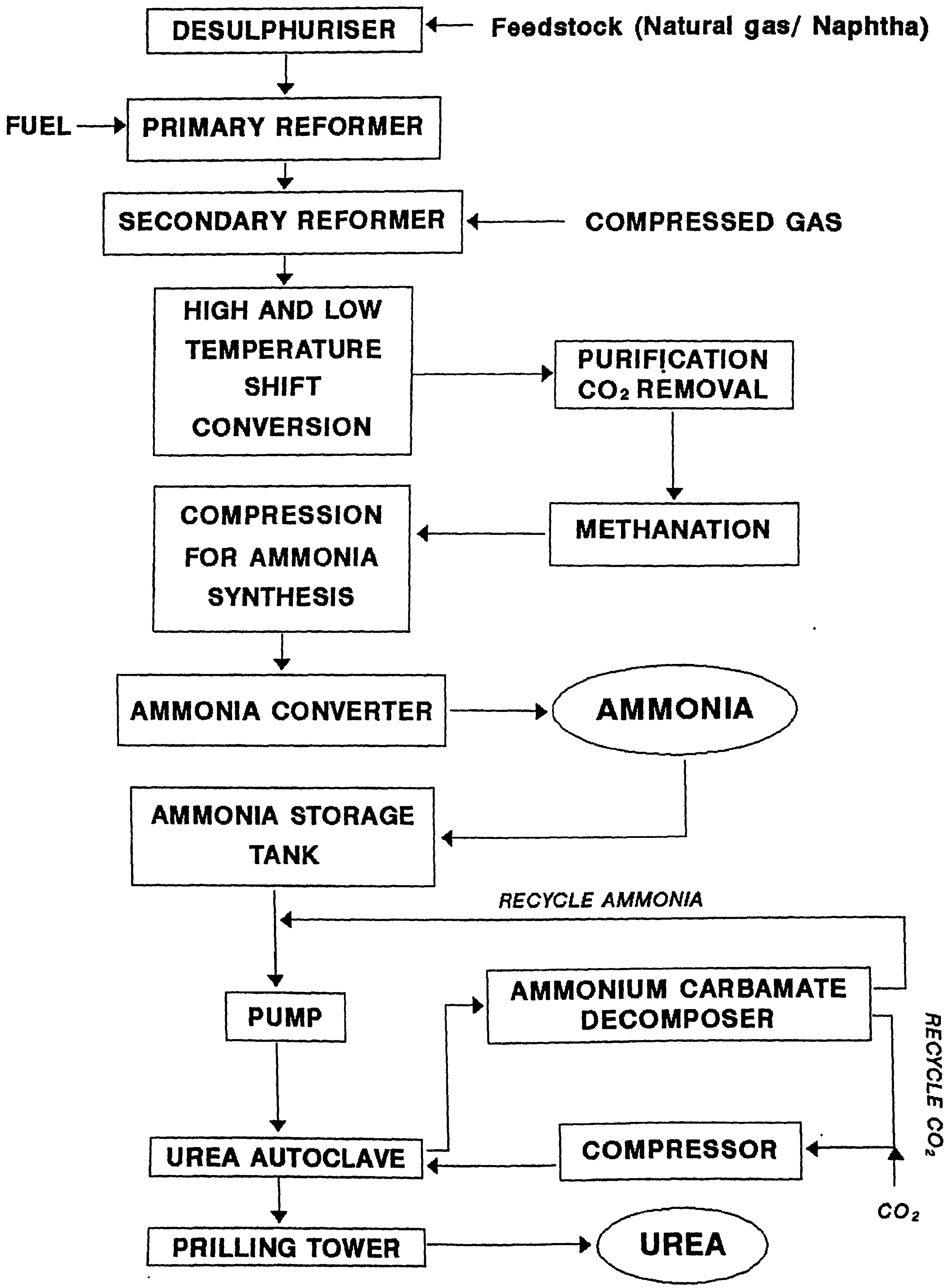
$CO_2 + 2NH_3 \rightarrow NH_2\ COONH_4$; $\Delta H = -37$ kcal/mole

This is then followed by an endothermic decomposition of ammonium carbonate to form urea.

$NH_2COONH_4 = NH_2CONH_3 + H_2O$; $\Delta H = 10$ kcal/mole

Figure 2 gives a simplified process flow diagram for ammonia and urea manufacture using natural gas/naphtha as feedstock.

Figure 2: Process flow diagram for Ammonia[13] & Urea production



CHAPTER 3

Energy profile

Fertilizer production and application constitute the major part in the energy consumption of agriculture sector. The manufacture, packing, transport and application of 1 kg of nitrogenous fertilizer require approximately 2 kg of fossil fuel, against around 0.3 kg of fossil fuel for phosphatic fertilizer. This shows that the production of nitrogenous fertilizer is more energy intensive than any other type of fertilizer production.

3.1 Ammonia plants

3.1.1 Capacity utilisation

India produced 8.65 million tonnes of ammonia in 1992-93 for the installed capacity of little over 10 million tonnes. Ammonia by far is the most important intermediate chemical which consumes more than 80% of energy required for producing nitrogenous or complex fertilizers. Therefore, the ammonia manufacture has always been focus of attention for energy conservation efforts in the industry. There are 35 medium to large size operating ammonia plants using coal, fuel oil, naphtha and natural/associated gas as feedstock. The choice of feedstock was dictated by the availability of energy resources from time to time.

Development of ammonia industry can be divided into three phases. In the first phase, plants were of small size (less than 600 TPD) and used reciprocating compressors. These plants were based on a variety of feedstock, viz., lignite, fuel oil, naphtha, natural gas, coke oven gas, water electrolysis, etc. Introduction of centrifugal compression for ammonia production initiated the installation of higher capacity single stream plants in the second phase. Therefore, a number of 600 and 900 TPD plants were installed in 70s. Eighties marked the third phase of ammonia industry by setting up most modern 1350 TPD plants using natural gas as feedstock. Fertilizer plants accounted for 40% of natural gas, 70% of naphtha and 26% of fuel oil consumption in the country during 1991-92. Feedstock-wise capacity and production of ammonia in 1992-93 is given in **Table 8.**

Table 8. Capacity & Production of Ammonia Plants

Feedstock	Capacity ('000 TPA)	Production ('000 TPA)
Natural Gas	5456.2	4687.2
Naphtha	3108.9	2256.5
Fuel Oil	1728.9	1575.7
Coal	594.0	133.4
Total	**10888.0**	**8652.8**

The better feedstock and process technologies together with improved operation and maintenance practices, scaling up of plants, revamping/retrofitting for removal of equipment deficiencies, installation of captive power plants etc. have resulted in significant improvements in energy consumption of ammonia plants. **Table 9** and 10 show the weighted average capacity utilisation and energy consumption of ammonia plants based on different feedstocks in India.

Table 9. Capacity Utilisation of Indian Ammonia Plants

	Capacity Utilisation (%)				
Feedstock	1989-90	1990-91	1991-92	1992-93	1993-94
Natural gas	92.5	98.7	94.5	96.4	93.6
Naphtha	72.3	75.7	81.3	80.3	76.1
Fuel oil	89.4	81.3	91.9	91.2	92.1
Coal	28.2	24.4	31.7	22.5	33.1
Industry weighted average	81.9	84.3	86.4	86.6	85.0

3.1.2 Energy consumption

The specific energy consumption of Indian ammonia plants for different feedstocks are given in **Table 10.**

Table 10. Specific Energy Consumption of Indian Ammonia Plants

	Specific energy consumption (GCal/MT)				
Feedstock	1989-90	1990-91	1991-92	1992-93	1993-94
Natural gas	9.62	9.63	9.55	9.48	9.41
Naphtha	12.35	11.92	11.74	11.73	11.70
Fuel oil	14.36	15.08	13.53	13.90	-
Coal	38.85	39.13	39.65	42.69	-
Industry weighted average	9.62	9.63	9.55	9.48	-

Most Gas based ammonia plants are performing close to or even better than design levels except plants at Namrup and Trombay. The average energy consumption of preliminary gas based ammonia plants in USA was 9.98 G Cal/MT for 1985-87 period. The lowest energy consumption achieved by an Indian plant on yearly basis is 7.83 G Cal/MT. The average energy consumption of latest gas based plants along HBJ pipe line is 8.0 G Cal/MT during 1992-93. Energy consumption of some of the gas based plants in the world is given in **Table 11.** These plants are comparable to the contemporary plants in India with respect to capacity, complete CO_2 recovery for Urea, cooling water temperature, etc.

Table 11. Energy Consumption of Gas Based Ammonia Plants (foreign countries)

Plant	Year of commissioning	Capacity ('000 MT)	Energy consumption (GCal/MT)
P.T. Pupuk Kaltim III,	1989	300.09	8.21 (1991)
ASEAN Bintulu Fert., Bintulu,	1985	306.0	9.19
Quatar Fertilizer Co., U.A.E.	1974	297.0	12.10

Their performance has also been similar to the Indian plants. The latest ammonia plants in India under construction (Aonla expansion and Vijaipur expansion) have the design energy (feed + fuel) consumption of 7.13 G Cal/MT.

Among the Naphtha based plants, SFC Kota had achieved the lowest energy consumption of 9.63 GCal/MT in 1993-94 and majority of other plants have operated at reasonable efficiency levels. There are a very few naphtha based ammonia plants operating around the world. There are two plants each in France, China and North Korea. Information on performance of these plants is not available. In the recent past major revamp programmes have been carried out by IFFCO Phulpur and SFC Kota which brought down the weighted average energy consumption of naphtha based plants. At present major revamp programme is planned at Madras Fertilizers.

Among the Fuel Oil based plants, the production performance of GNFC and three NFL plants has been consistently good. The energy consumption of NFL plants has been somewhat higher than design. The performance of the other two plants at Sindri and Neyveli has not been so good in recent years due mainly to equipment problems.

Among the Coal based plants, production performance of the two coal based plants has not been good and that is the main reason for their very high specific energy consumption. The poor quality of coal, power supply interruption and equipment design deficiencies have caused frequent shutdown and lower load of these plants. This resulted in low production and high unproductive energy losses.

3.2 Urea Plants

There are 33 urea plants operating in the country varying in capacity from 300 TPD to 2200 TPD with single prill tower. The technologies used are total recycle, modified recycle and ammonia/CO_2 stripping supplied by Motedison, Stamicarbon, Mitsui-Toatsu, Snamprogetti and others.

About 80% of energy consumption in urea production goes through ammonia plants. Therefore, efficiency of ammonia plant effects the total energy consumption of urea plant. However, ammonia consumption per tonne urea and steam and power consumption in urea plant battery limit are the parameter which reflect its energy efficiency.

Urea plants can be classified according to their vintage. **Table 12 and 13** show the share in capacity, capacity utilisation, ammonia consumption and energy consumption for various categories of plants based on their period of commissioning. It can be seen that a substantial capacity (47.9%) of total has been added in 1980s. The plants commissioned in eighties have better capacity utilisation and lower energy consumption. This can be attributed to adoption of latest technology, larger plant size and more energy efficient ammonia plants, It can be mentioned here that some of the earlier plants have not performed well due to limitation in availability of ammonia due to poor performance of ammonia plants. Total energy consumption of urea plant generally varies from 5.7 Gcal/MT to 13.0 Gcal/MT with weighted average of 8.1 Gcal/MT urea. IFFCO Aonla has the lowest energy consumption of 5.68 Gcal/MT in 1992-93. The plants like Ramagundam, Talcher, Durgapur, Barauni have very high consumption which is reflected in the performance of plants commissioned during 1976-80 period.

The efficiency of urea stand alone plant can be gauged if the total energy is broken up into its elements. The elements of efficiency measurement for urea plant are specific consumption of ammonia and specific consumption of utilities (steam + power). The consumption of utilities is reported in equivalent calorific value and called conversion energy. These figures for various categories of plants are reported in Table 5.14. It is evident again that ammonia consumption and conversion energy have progressively come down over the years.

The total energy of urea plants commissioned during 1976-80 is higher than plants of earlier period, but the ammonia consumption and utility figures are lower than plants of earlier periods. This shows that the efficiency of urea plant is good and fits into the trend observed. But due to inefficiency of ammonia plants the total energy figure represents a somewhat distorted picture.

The average specific ammonia consumption of Indian urea plants is 0.588 MT with a range of 0.574 to 0.668. The latest plants are achieving the ammonia consumption very close to practical minimum of 0.570 MT/MT of urea.

The average conversion energy of 1.46 Gcal/MT is better than 1.84 Gcal/MT reported for urea plants in United States. The range of 1.02 to 2.62 Gcal/MT is also lower than range of 1.46 to 2.74 Gcal/MT reported for the American urea plants. It should be mentioned here that most American plants are old as compared to a mix of new and old plants in India. Nevertheless, the fact remains that the performance of even old plants (before 1970) in India is comparable to that of American plants. The latest plants in India have achieved the conversion energy figure of less than 1.0 Gcal/MT. The performance data shows that there is a scope for improvement in both specific ammonia consumption and conversion energy of urea plants. The gap in the technology of the old plants and the

present state of art of technology and the measures available to bridge this gap are discussed in the next chapter.

Table 12. Capacity build-up of urea plants

Commissioning Period	No. of Plants	Share in Capacity (%)
Before 1970	9	16.6
1971-75	6	14.8
1976-80	7	20.7
1981-85	5	20.2
1985 onwards	6	27.7
Total	**33**	**100.0**

Table 13. Capacity utilisation and energy consumption in urea plants

Commissioning Period	Capacity utilisation (%)	Specific ammonia consumption (Gcal/MT)	Conversion energy (Gcal/MT)	Total energy (Gcal/MT)
Before 1970	83.9	0.60	1.89	8.73
1971-75	87.2	0.59	1.46	8.73
1976-80	60.2	0.59	1.24	11.26
1980-85	105.5	0.58	1.48	7.64
1985 onwards	110.2	0.57	1.28	6.16
Weighted average	91.1	0.58	1.46	8.09

3.2.1 Downtime

Natural gas supply cut off or restrictions in supply from GAIL and equipment failures have resulted in significant production losses both in ammonia and urea plants. **Table 14 and 15** show the statistics for both the plants of KRIBHCO, which is considered as one of the better plants in India:

Table 14. Production Loss Due to Natural Gas Supply Cut off/Restriction

	Production loss (MT)	
Year	Ammonia	Urea
1985-86 (Dec-Jun)	Nil	Nil
1986-87 (Jul-Jun)	270	Nil
1987-88 (Jul-Jun)	499	Nil
1988-89 (Jul-Mar)	19035	254580
1989-90	7406	8075
1990-91	28147	45470
1991-92	29245	43037
1992-93	9830	54977
1993-94	20874	42926

Table 15. Production Loss Due to Equipment Failure

	Ammonia plant		Urea plant	
Year	Day	Production loss (MT)	Day	Production loss (MT)
1985-86 (Dec-Jul)	Nil		Nil	
1986-87 (Jul-Jun)	0.52	1411	0.59	2667
1987-88 (Jul-Jun)	3.45	8907	11.20	49262
1988-89 (Jul-Mar)	2.46	6888	5.92	16061
1989-90 (Apr-Mar)	8.34	22524	10.64	42630
1990-91	1.15	3112	5.64	24837
1991-92	5.43	14667	9.97	48069
1992-93	10.44	27181	1.82	8009
1993-94	1.89	5099	7.76	34168

Note: Does not include the production loss of 33101 MT of ammonia and equivalent urea due to explosion/fire accident in one unit in Sep-Oct 1991.

It could be seen from the tables that production loss due to equipment failures has come down appreciably in 1993-94 in Ammonia plant.

3.3 Case study

The actual energy data for 10 ammonia and urea plants was collected, which shows a very diverse energy consumption trend in the industry. This was mainly due to different feedstocks, technology and vintage of Indian plants. The overall energy consumption for the ammonia and urea plants is presented in **Table 16.**

Table 16. Energy Consumption of Ammonia & Urea Plants

Plant	Feedstock	Ammonia (Gcal/MT)	Urea (Gcal/MT)
National Fertilizers Ltd. (NFL), Vijaipur	Gas	8.09	6.14
Krishak Bharati Cooperative Ltd. (KRIBHCO), Hazira	Gas	8.83	6.31
Nagarjuna Fertilizers & Chemicals Ltd., Kakinada	Gas	8.22	6.50
Indian Farmers Fertilizer Cooperative Ltd. (IFFCO), Phulpur	Naphtha	10.52	7.73
Shriram Fertilizers & Chemicals (SFC), Kota	Naphtha	9.58	7.41
Gujarat State Fertilizer Co. Ltd. (GSFC), Baroda	Naphtha	9.36 (Plant I) 9.86 (Plant II)	7.52
The Fertilizer Corporation of India Ltd. (FCI), Sindri	Fuel Oil	15.43	11.03
National Fertilizers Ltd. (NFL), Nangal	Fuel Oil	15.73	10.41
Gujarat Narmada Valley Fertilizers Co. Ltd. (GNFC), Bharuch	Fuel Oil	11.95	7.90
The Fertilizer Corporation of India Ltd. (FCI), Ramagundam	Coal	32.26	21.27

It could be seen from the above table that the energy consumption of gas based plants varied from 8.09 Gcal/MT of ammonia for NFL Vijaipur to 8.83 Gcal/MT of ammonia for KRIBHCO Hazira. The performance of Indian gas based plants compares well with similar plants in foreign countries. While making comparison with foreign plants, a number of factors have to be kept in mind. Ammonia plants in India recover carbon-di-oxide completely for urea production, while most plants in USA and Europe do not do so due to different downstream products. The cooling water temperature is also lower in cold countries than that in India. These factors together can make a difference of 0.2-0.3 Gcal/MT of ammonia.

Energy consumption of naphtha based plants ranged from 9.36 Gcal/MT for GSFC Ammonia I plant to 10.52 Gcal/MT for IFFCO Phulpur plant. But it should be mentioned here that GSFC plant use a mixed feed of gas and naphtha. Fuel oil based plants have energy in the range of 11.95 Gcal/MT for GNFC Bharuch to 15.73 Gcal/MT for NFL Nangal ammonia plant. While GNFC Bharuch is the best fuel oil based plants in India, Sindri plant suffers from several design deficiencies which have not been rectified. Performance of coal based plant at Ramagundam has been poor mainly because of equipment deficiencies, power and coal problems, etc. Comparable figures for naphtha, fuel oil and coal based plants are not available for foreign countries.

3.4 Factors of higher energy consumption

Energy consumption in manufacturing a product is a cumulative effect of several technological factors. Some of these factors as applicable to fertilizer industry are outlined here briefly.

3.4.1 Feedstock

Natural gas is the best feedstock for ammonia production. However, 52% of ammonia capacity is based on feedstocks other than gas. Naphtha based plants would have design energy consumption 10% more than gas based plants. Similarly, fuel oil based plants would have 15% more and coal based plants 45% more energy consumption than gas based plants. This has put Indian plants at disadvantage of higher design energy consumption.

3.4.2 Vintage

About 12 ammonia plants are more than twenty years old. These plants have high design energy consumption. Two of them have implemented major modernisation programmes to increase the capacity and reduce the energy consumption. These plants have now been able to achieve energy consumption lower than their original design energy.

Modernisation/replacement of other three plants is also on the anvil. One of them (FCI Gorakhpur) is closed since 1990. Investment of high order is required to extend the life of old plants and make them energy efficient. Therefore, replacement of old capacity may be the only solution in some cases. There is another set of 9 plants which are 15-20 years old. Most of them are operating well but need revamp/retrofit to improve energy efficiency.

3.4.3 Capacity utilisation and on-stream days

Energy consumption of a plant is related to its capacity utilisation and on stream factor. Because steady run at high loads results in least unproductive losses and lowest specific consumption of energy. As has been shown in previous chapter that as the capacity utilisation of plants has improved, energy consumption has come down. Capacity utilisation of Indian ammonia plants was 86.6% and 91.3% for urea plants during 1992-93. There is a room for Indian plants to improve the operating factor and hence improve energy efficiency.

3.4.4 Maintenance efficiency

Fertilizer plants are complex continuous process plants, therefore, these have to be maintained well for obtaining high operating factor and efficiency. It has been demonstrated by the decrease in downtime of one of the ammonia plants that maintenance of these plants has improved significantly over the years. Downtime due to mechanical failures in Indian ammonia plants has come down from 39.3 days/plant/year in 1980-84 period to 19.3 days/plant/year during the 1990-93 period, which speaks volume of improvement in plant performance. Application of non-destructive techniques (NDT) for monitoring the health of plant and equipment and adoption of predictive and preventive maintenance strategies have improved the performance of fertilizer plants. However, average number of shutdown 24.4/plant/year is still large and this can be reduced in plants whose performance has deteriorated during last few years.

3.4.5 Performance of equipments

As stated earlier, fertilizer plants operate at high temperature and high pressures. Operations at cryogenic temperatures are also there. Large waste heat recovery and utilisation involves use of large number of heat exchangers. Amongst moving machines, compressors and pumps which are either turbine driven or power driven consume large energy and their efficiency i.e., stream or power consumption affects the overall energy consumption. Other equipments like fans, blowers etc. are also important. Improvement in design of turbines and fans and their maintenance can help to achieve the lower energy

consumption. For example, by changing the steam turbine of CO_2 compressor, IFFCO Phulphur has been able to achieve savings of 15 Te/hr of HP steam. Amongst static equipment are reformer tubes, furnaces, heat exchangers, valves, etc. whose design maintenance and material of construction play an important role in energy efficiency. For example, reformer tubes of improved metallurgy have better heat transfer characteristics and lower pressure drop to save energy.

3.4.6 Catalyst

Upto 7 no. catalyst are used in ammonia plant. Activity and strength of catalyst is of utmost importance for energy consumption of plant. For example, in synthesis loop with reduction in catalyst activity, conversion per pass would go down and recycle would increase to reduce the energy efficiency. Similarly, crumbled catalyst in any vessel would result in high pressure drop which requires higher energy to push the same amount of gas through the plant. Development in the area of catalyst science has helped the ammonia plant operators to operate at lower pressures and temperatures in various sections. For example, new synthesis catalyst of finer size is more active and gives higher conversion per pass which alongwith change in converter baskets could result in energy saving of upto 0.25 Gcal/MT of ammonia. Research & developments in catalysts would help bring down the synthesis pressure further and hence savings in energy for compression.

3.4.7 Process considerations

The development in various process steps of ammonia, urea, sulphuric acid and phosphoric acid plants have helped to improve the design energy consumption of new plants. Adoption of process technology developments could help reduce the energy consumption in existing plants. For example, most of old generation plants are to be retrofitted particularly reformer, CO_2 removal and synthesis section of ammonia plant, urea reactor in urea plant, etc. Integration of various process steps and heat recovery system could result better waste heat utilization. A lot of this integration already exists in ammonia and urea plants but the continuous efforts are needed in the old plants.

3.4.8 Utilities

Majority of the ammonia-urea plants have captive power plants to insulate from the vagaries of State grids. With the availability of natural gas, the latest captive power plants use gas turbine for power generation and cogeneration of steam using heat recovered from exhaust gases of gas turbine. This arrangement gives higher overall energy efficiency. However, efficiency of these systems has been adversely affected due to non-availability/

restrictions in supply of gas. As alternative arrangements, liquid fuels like naphtha and NGL are being fired in the gas turbine.

Other utilities like fired boilers, cooling towers, water and effluent treatment facilities, etc. are also part of the overall energy scenario. There have been efforts to improve the efficiency of coal fired boilers in some plants by improvement in burner design, heat recovery system, excess air control, microprocessor based control system, etc. However, the biggest bottleneck here remains the quality of coal which affects throughput and efficiency of boilers.

Similarly, efforts have been made to improve the material and design of cooling tower fans which could cut down the power consumption by as much as 35%. Efforts to reduce the water consumption and hence the reduction in quantity of effluents also helps in saving in energy spent in treatment of raw water and effluents.

3.4.9 Optimisation of plant operation

Control of process parameters within optimum limits not only helps in smoother operation of plants but also results in some savings in energy. The order of savings may vary from 0.5 to 1.5% depending on the extent of optimisation. Optimisers work either in advisory mode where actual controls are left to plant operator or in close loop made where control valves are automatically fed to the controllers. Needless to say that later method requires more sophisticated system. A number of plants viz., RCF Thal, KRIBHCO Hazira and Nagarjuna Fertilizers have adopted the distributed control system to operate plants within desirable range of parameters. Optimisation of plant operation not only results in benefits when plant is operating at full load but even at part load. Lower plant loads might result due to shortage of feedstock and/or fuel or market limitations.

3.4.10 Low level heat utilisation

A difficult area in reduction of energy consumption is maximum recovery and utilisation of low level heat in the form of LP steam. Systems for upgradation of low level heat have not proved their viability on commercial scale. In one of the latest plants, LP steam is injected in the compressor turbine. In another case it has been reported that the low level heat has been utilised for preheating the combustion air and feed hydrocarbon. Some R&D efforts are required for economic utilisation of low level heat.

3.4.11 Energy management

Energy management in a plant should include energy measurement, monitoring of consumption under various heads, suggestions for improvement on day to day basis,

proposals for energy conservation projects, creating energy consumption data base for that particular plant and similar other plants in India and abroad, etc.

Technical service departments in all the plants are normally responsible for the energy management and conservation. These departments in many cases are not able to do justice to the task at hand. There is urgent need to strengthen these departments both in terms of manpower and equipments. Energy measurement equipments are necessary for the internal energy audit of the plants. Computers are absolutely necessary to record and retrieve the energy related information.

Needless to say that flow of energy related information should be smooth to different departments and senior management. Commitment of top management is absolutely essential for the success of energy conservation efforts.

CHAPTER 4

Energy conservation opportunities

Ammonia plants in India can be classified into three categories. In the first category are the ammonia plants which suffer from design deficiencies and mismatch of equipment. They need heavy investments for revamp/retrofit/replacement of equipment to bring them to the reasonable production levels. Barauni, Durgapur, Namrup, Ramagundam, Talcher, Sindri and Gorakhpur plants of FCI are examples of such plants. At present their capacity utilization levels are low and energy consumption is much higher than design/guaranteed levels. Needless to say that the modernization measures would improve the energy efficiency of these plants by way of higher capacity utilization and installation of more energy efficient equipment.

There is a second category of ammonia plants which suffer some design problems but their performance has been reasonably good. Capacity utilization of these plants stayed in the range of 70-90%. Energy consumption of these plants has been somewhat higher than design/guaranteed figures because of capacity and performance bottlenecks in some sections of the plants. NFL Nangal, FACT Cochin, RCF Trombay, MCF Mangalore, MFL Madras are the plants which may be classified in this category. These plants need investments for revamp/retrofit/replacements to improve their capacity utilization and energy efficiency.

The plants which fall in the third category are naphtha based plants at Phulpur, Kanpur, Goa, Kota, Tuticorin and Baroda, fuel oil based plants Bhatinda and Panipat and gas based at Kalol. These plants have achieved high capacity utilization and energy consumption close to design levels. But most of them require upgradation of technology and equipments to prolong their life and to achieve the energy consumption even lower than their original design. The reason that some of these plants in spite of being more than 20 years old are still performing well is the continuous upgradation including installation of new capital equipment.

Lastly there are plants which have been commissioned in eighties and with the exception of GNFC Bharuch, utilize natural/associated gas as feedstock. Plants at Thal, Hazira, Aonla, Vijaipur, Jagdishpur and Kakinada fall in this category. These plants have consistently produced more than their installed capacity with energy consumption very close to their design levels. These plants have the scope for improvement in their energy consumption with appropriate technological upgradation and optimization of operating parameters. Of course, scope of improvement is limited since some of the latest measures were incorporated at design stage itself.

4.1 Ammonia Plants

Energy consumption in ammonia plants affects energy consumption of urea and other downstream plants. Theoretical energy consumption of ammonia manufacture based on natural gas is estimated at 5.5 Gcal/MT of ammonia. If this figure is estimated at LHV of methane the theoretical minimum consumption of ammonia production is 4.9 Gcal/MT of ammonia. These figures do not reflect energy requirement for other infrastructure. However, even if we take these figures the lowest energy consumption in an Indian plant on yearly basis is 7.83 Gcal/MT. Thus the efficiency based on LHV of natural gas is around 63%, but if we take the average all India figure of about 9.48 Gcal/MT NH_3 for gas based plants the efficiency comes down to 52%. The balance energy is lost through cooling water, through stack, radiation losses and miscellaneous losses, e.g., steam vent, etc. But from the figures reported in ICI LV on the energy efficient process, the efficiency level is more than 70% in the battery limit plants. Energy efficiency of Indian plants is inherently little lower than American and European countries due to higher cooling water temperature and complete recovery of high purity CO_2 for manufacture of urea.

But, there is considerable scope for energy saving in various section of the ammonia plants. Increasing efficiency levels beyond a certain limit, though may be technically feasible, is not economical or cost effective; therefore a trade off has to be struck between efficiency level and investment required. In the **Table 17**, the relative energy requirement of various feedstock is indicated.

Table 17. Relative Investment and Energy Requirement for Ammonia Plant

Sl. No.	Feedstock	Relative energy requirement	Relative capital investment
1.	Natural Gas	1.00	1.00
2.	Naphtha	1.10	1.15
3.	Fuel oil	1.15	1.50
4.	Coal	1.45	1.90

As discussed earlier, a significant part of ammonia capacity in Indian fertilizer plants are old and their energy consumption levels are typically in range of 9-11 G Cal/MT ammonia or even higher. The investment required for implementing technological innovations and improved measures in old plants to bring them to the state of the art level of new low energy plants are prohibitive. However, improvement measures of minor or major nature can be implemented after a careful cost benefit analysis. These measures would be tailor made for the specific plant for optimizing production and energy consumption.

Production of ammonia is a multistage process involving high temperature and high pressure reactions and various unit operations. Various energy conservation options in ammonia plant, process stage wise (i.e., in gas making, gas purification and ammonia synthesis) are given below.

4.1.1 Gas Making

In gas making, primary reforming is the major energy consumer. Reformers in old plants have about 85% thermal efficiency which has been improved to 93% in recent reformers. The increase in efficiency has been possible due to preheating of combustion air; low stack temperature, less heat loss through insulation of reformer box and excess air control. There are several other options available to improve the primary reformer efficiency. For example, reduction in steam-carbon ratio would result in reduction in pressure drop and reduced firing. Use of superior tube metallurgy allows use of thin walled reformer tubes and hence increased catalyst loading. This would result in higher reforming capacity and reduction in specific energy consumption. Feed gas saturation and use of gas turbine for process air compressor along with use of exhaust as pre-heated combustion air can result in saving the process steam and reformer fuel. In another energy saving measure, part of the reforming load can be shifted to the secondary reformer which is thermally more efficient. Some of the specific measures are discussed in detail.

4.1.1.1 Reformer tubes of superior material

The first generation ammonia plants in India used HK 40 as material for reformer tubes. Advantages of alloys with superior creep rupture properties led to the development of 24 Cr 24 Ni Nb (IN-519). Recent centrifugally cast alloy development was directed towards the basic HP alloy, i.e. alloy containing 25 Cr-35 Ni with 0.4%-0.5% Carbon. Addition of Nb significantly increased the high temperature creep strength, thereby establishing the superiority of alloy.

Approximately, 40-60% higher strength compared to HK-40 alloy, significantly lowers tube wall thickness and has become a very attractive proposition for revamp of ammonia plants. The studies reveal that for the same ammonia production, there can be an energy saving of 0.020 to 0.025 G Cal/tonne ammonia. The replacement of existing 24 Cr 24 Ni Nb reformer tubes with that of HP-Nb alloy may give a payback period of about an year under suitable conditions.

4.1.1.2 Adiabatic pre-reformer

Adiabatic pre-reformer is a shaft type reactor and normally precedes the externally fired tubular reformer. Recently, interest in using a pre-reformer has grown considerably. An adiabatic pre-reformer can be installed as a part of revamp for capacity increase and/or energy savings in existing ammonia plant. The most attractive feature of the adiabatic pre-reformer is its simplicity, with the requirement of only a shaft reactor along with an active reforming catalysts operating at moderate temperatures.

Adiabatic pre-reforming can be used for steam reforming of hydrocarbon feedstocks ranging from natural gas to heavy naphtha with final boiling points above 200°C and aromatic content upto 30%. Desulphurized hydrocarbon, mixed with process steam enters adiabatic pre-reformer where the higher hydrocarbons are completely converted into a mixture of carbon oxides, hydrogen and methane, by overall endothermic reaction. This reaction is followed by exothermic methanation and shift reactions. For a typical natural gas feed, the overall process is endothermic resulting in temperature drop, while for heavier feedstocks such as naphtha, the overall process is exothermic or thermoneutral. The inlet temperature to the adiabatic pre-reformer ranges between 375°C to 525°C, depending on nature of feedstock and steam/carbon ratio.

For a typical 1350 tonnes/day natural gas based ammonia plant, the energy savings (coupled with the effect of reduced steam/carbon ratio) is expected to be 0.20 G Cal/tonne ammonia. Considering an additional cost of equipments, piping, valves, instruments, etc. for inclusion of a pre-reformer in existing large ammonia plant, the payback period will be about 2 years.

4.1.1.3 Reduction of steam/carbon ratio

Reduction of steam/carbon ratio is one of the prerequisites for incorporation of a pre-reformer for revamp in ammonia plant. Reducing the steam/carbon ratio will also decrease the process gas side pressure drop in the front end and will result in lower steam production in the waste heat boilers, which is compensated by the reduced process steam requirement. The reduction in the quantum of steam superheat (due to reduced flow) inside the reformer tubes, is reflected in reduced firing rate in primary reformer. Considering installation of a pre-reformer along with active pre-reforming catalyst, upstream of primary reformer, the risk of carbon formation and consequent hot-bands can be avoided.

The reduction in steam/carbon ratio represents a change in the operating parameter of the plant. The resultant effect in energy savings has thus to be viewed with the operating parameter of the plant. The resultant effect in energy savings has thus to be

viewed with the overall effect in steam network along with changes in feed/fuel consumption patterns.

4.1.2 Gas purification

The percentage conversion in the LT shift reactor has significance with regards to loss of hydrogen or rate of ammonia production. For an ammonia plant based on classical route, it has been estimated that, for increase in CO by 0.1% at the LT shift reactor outlet, ammonia production will decrease by approximately 1%. The LT shift reaction stage being equilibrium controlled, there exists the possibility of 'trade-of' between additional catalyst volume charged and energy savings derived thereof. Depending on the "trade-off", the energy savings varies between 0.05 to 0.085 G Cal/tonne ammonia.

4.1.2.1 Use of hydraulic turbine

In comparatively older generation plants, rich solution from CO_2 absorber bottom passes to regenerator top, through a level control valve, where the pressure of the solution is brought down from a high pressure level to a low pressure level. A hydraulic turbine can be installed in combination with level control valve, as an energy saving measure. For a 900 MTPD ammonia plant estimated power generation is of the order of 340 kWh. This amounts to an energy saving of approximately 0.025 G Cal/tonne ammonia with payback period of more than 6 years.

4.1.2.2 Four-stage flash vessel

Almost all hot potash based carbon dioxide removal units, use stage-wise flashing for generation of vapours, which are reused in the regenerator. The single-stage flash system in the older generation plants can be effectively replaced with the four-stage flash system, as an energy saving measure. The benefit desired by implementation of a 4-stage flash system, shall be in terms of reduction of LP steam import. For a 1000 MTPD ammonia plant, the energy saving works out to approximately 0.022 G Cal/tonne ammonia such the indicated payback period is long i.e. of the order of 7 years.

4.1.2.3 Change of tower packings

Keeping pace with technological upgradation in carbon dioxide removal processes, better types of tower packings have also emerged in the market. Some of them, like Norton's IMTP, cascade mini-rings, Nutter packing, structured packings like MELAPAK etc., are proven types and are successfully operating in many plants. Replacement of older tower packings, like rasching rings, pall rings, etc., with aforesaid packing, shall result in

manifold benefits, like capacity increase, easier operation, lower carbon dioxide slip from absorber, etc.

4.1.3 Ammonia synthesis

The design of ammonia synthesis loop together with synthesis converter is standardized and very little scope exists for radical improvement in energy efficiency. Except for changeover of older design like multiple-bed quench cooled converter to standard design like radial or axial-radial type with 3-5 mm size catalyst in some of the plants, the major revamp measures are directed towards overcoming the deficiencies in synthesis gas compressor and refrigeration compressor.

However, the installation of a purge gas recovery unit, though termed as an adjunct to the synthesis loop, is carried out on considerations, irrespective of the performance of synthesis loop. Salient features of some of the energy/revamp measure in synthesis section are described below:

4.1.3.1 Purge gas recovery unit

The process gas make up supplied form the front end section to the ammonia synthesis loop, for plants based on "classical" route, contains inert like methane, argon, traces of carbon oxides besides synthesis gas mixture of hydrogen and nitrogen. A calculated amount of recirculating synthesis gas mixture is required to be purged from the synthesis loop for maintaining pre-determined level of inerts in the loop. The purge from the loop contains a substantial amount of synthesis gas mixture of hydrogen and nitrogen along with the inerts. The purge rate depends on inert content in make-up synthesis gas together with some key process parameters like pressure and inert-level of the loop.

Part of the key component, hydrogen in purge gas, ca be recovered by utilizing this purge gas as a fuel for the primary reformer. But this recovery, in the form of heat value, is only partial. Hydrogen loss with the purge gas can be reduced substantially by installation of a Purge Gas Recovery Unit, which can be either cryogenic, PSA or membrane type. The installation of a purge gas recovery unit is very simple, as it is just an add-on to any existing synthesis loop. Energy saving of the order of 0.20 G Cal/MT ammonia can be achieved.

4.1.3.2 Make-up gas chiller at suction

Make-up gas chiller can be provided at the suction, as a means for marginally increasing existing capacity of the synthesis gas compressor. Installation of make-up gas chiller at the first stage suction, along with chiller in the downstream of existing water-coolers at each interstage of the compressor, can be meaningful proposition. A separate refrigeration

unit for supplying cold to the chillers can ensure a trouble free operation by avoiding the undesirable risk of overloading the existing refrigeration compressors.

An energy saving of approximately 0.10 G Cal/tonne ammonia can be achievable by implementing this revamp measure.

4.1.3.3 Synthesis converter revamp

Reduction in synthesis pressure results in savings of energy in compression. With the development of low temperature and low pressure catalyst, it is possible to achieve relatively high conversion at low pressure. The pressure drop across the converter can be reduced with radial gas distribution in catalyst bed. The improved ammonia syn. converters generally incorporate interbed heat exchanger instead of quench type converter for better thermal efficiency. The existing plant can save energy of the order of 0.2-0.30 GCal/MT with the revamp/change of converters.

MFL replaced their original chemico axial flow converter with the Topsoe S-200 radial converter achieving an energy saving of 0.29 G Cal/MT. The new converter is designed for operating pressure of 180-190 kg/cm_2 compared to 232 kg/cm_2 of chemico converters.

In a 22 year old naphtha based plant, the Topsoe S-100 converter was revamped with S-200 basket in April 1992. It enhanced the production capacity of loop by more than 150 TPD and the loop pressure was reduced from 310 to 270 kg/cm^2. This change along with other revamp measures and change of almost all the catalysts effected an energy saving of about 0.4 G Cal/MT.

KRIBHCO, Hazira and IFFCO, Phulpur and Kalol plants have also changed the internals of their Kellog converter with Ammonia-Casale radial-axial baskets in 1993. The new catalyst used in all the revamped converters is highly active with size of 1.5-3.0 mm as compared to the 6-10 cm size catalyst before revamp, resulting in higher conversion per pass. Several other plants are likely to implement this measure in near future.

4.1.3.4 Computer control and optimization

Computer control of critical parameters in ammonia plant provides another opportunity for saving energy and increasing production. Some of the parameters which can be put on control are air-fuel ratio, steam carbon ratio, methane slip from secondary reformers, H/N_2 ratio in synthesis gas, purge rate, synthesis converter quench distribution etc. With the help of process control models and multivariable control methods, a computer can maintain the plant in an operating mode to minimize energy consumption and/or maximize plant production. Computer control has been made possible by the installation of distributed digital control (DDC) system and optimisers in the plants. The investment

could vary from a few crores to several crores of rupees depending on the number of parameters to be optimized and controlled and level of instrumentation in the existing plant.

RCF Thal has installed advanced control system for automatic control of four critical parameters viz. steam/carbon ratio, H_2/N_2 ratio in make up gas, inert level in syn loop and reformer firing control. These plant parameters are continuously monitored, optimum values of set points are calculated and fed to the controllers with DCS interface. Thus optimum plant conditions are maintained and 1-2 percent savings in energy consumption are obtained. KRIBHCO, Hazira has also installed optimisers separately on the two ammonia plants. One of them would work in advisory mode and the other like Thal in close loop with the plant controllers. IIT, Delhi and IIT, Bombay have developed software for off-line optimization of ammonia plant operation.

4.2 Urea Plant

Production of urea is a high pressure and moderate temperature reaction between ammonia and carbon-dioxide. About 80% of energy required for urea production is drawn from ammonia. Hence reduction and prevention of ammonia losses in the plant helps in reduction of energy consumption in urea plant. There are a number of developments which help reduce ammonia and utility consumption in urea production.

Conventional total recycle process was replaced by modified total recycle process technology where the heat of condensation of unconverted ammonia and CO_2 generated in HP decomposition stage is usually recovered as LP steam. With the advent of stripping technology, carbamate decomposition and condensation are carried out at synthesis pressure. It helps in efficiency of operation and energy reduction. There are about 17 urea plants in India based on total recycle process without heat recovery. The existing plants can be revamped with energy efficient technologies like ACES, IDR, SRR and UTI processes. MFL proposes to revamp its urea plant with UTI heat recovery process.

As in the ammonia plant, critical parameters in urea plants like ammonia-CO_2 ratio in the reactor, the carbamate recycle concentration and reactor temperature can be put on automatic control, allowing the plant to operate under the most stable and optimum conditions.

Some of the most promising energy conservation measures for urea plants are discussed below.

4.2.1 Urea hydrolyser stripper

Ammonia and urea losses through waste water can be reduced by the installation of urea hydrolyser-stripper. Lost ammonia and urea are recovered and recycled back to the

system. This not only improves the efficiency but also helps in pollution abatement. New plants have this facility from the design stage itself. Several old plants viz. IFFCO - Phulpur, Kalol; FACT - Cochin, NFL - Nangal, etc. have added urea hydrolyser-stripper to their facilities.

4.2.2 Incorporation of trays inside the reactor

Sieve trays installed in urea synthesis reactors play an important role in improving urea process technology. These trays prevent back mixing and in turn increase the conversion efficiency. There are possibilities for improvement in the design of these sieve trays. The use of normal sieve trays, although significantly improve the reactor's performance but does not completely solve the problems, because the simultaneous gas and liquid flow on each sieve tray produces negative consequences also, which in turn affects both heat and mass transfer between the two phases. In fact, vapour and liquid cannot simultaneously cross the perforation of the flat tray, but are forced to do so in an alternated pattern, thus maintaining a certain segregation between the two phases. With the new trays it is possible to obtain a more uniform distribution of the gas bubble in the liquid phase with a consequent increase in urea yield and reactor capacity. The use of efficient trays can increase the conversion yield by 2 to 5%.

4.2.3 Use of coil to feed the reactants from top of reactor

One of the most prominent features of the Heat Recycle process is the adiabatic isothermal urea reactor design with its internal open-ended reactor feed coil, which is unlike all the conventional urea reactor designs having a bottom reactor feed system. In such a conventional system, the bottom section of the urea reactor tends to become overheated due to exothermic reaction between carbon dioxide and ammonia to produce ammonium carbamate. As a result, much of the gaseous carbon dioxide fed to the reactor bottom does not react because of the substantial increase in vapour pressure of ammonium carbamate and thereby passes unreacted from the reactor. There is an overall drop in conversion of gaseous carbon dioxide to urea with adverse effect on the utility consumptions in the subsequent decomposition section.

UTI's reactor receives its feeds at the top, directly into an internal open-ended coil made of high chrome alloy that is impervious to corrosion. The exothermic reaction of gaseous carbon dioxide to carbamate occurs inside the coil. Simultaneously, there is indirect counter-current exchange of heat with the relatively colder solution that is rising through the reactor outside the coil and which is undergoing the endothermic conversion of carbamate to urea. Part of the ammonia feed to the reactor is delivered to the reactor bottom section, which is relatively, the coldest section of the reactor, operating at around

177°C. Hot spot in the reactor are thus eliminated, and there is also a considerable increase in conversion and total elimination of corrosion of the standard 316L rector liner. Conversion per pass as high as 75% have been determined in UTI's reactor operating at about 218 kg/cm^2 g pressure and about 196°C temperature.

4.2.4 Use of internal heat recovery system

In a conventional urea process the unconverted ammonia and carbon dioxide separated from the urea reactor effluent are condensed in an absorption system, and the ensuing heat of reaction is rejected to cooling water. This is an energy loss and efforts have been made by major process suppliers to utilize the heat of condensation, which is liberated by the condensation of NH_3, CO_2, and H_2O in condenser. These vapours are formed by decomposition of carbamate in the reactor effluent in different carbamate decomposers. Initially the heat of condensation in the carbamate condensers was used only for rasing LP steam, which was partly used for concentration of urea solution and rest was exported. Even with this measure large amount of heat in MP and LP condensers was wasted in cooling tower, processes like UTI-Heat Recycle Process, ACES and IDR process have further improved the technology of *Internal Heat Recovery* and has saved considerable energy, which was hitherto lost in cooling tower.

4.2.5 Vacuum pre concentrator

Ammonia self-stripping results in solution at the stripper outlet having a rather high NH_3/CO_2 ratio, thereby requiring a medium pressure section to distill excess ammonia. On the other hand, this section offers the opportunity of achieving a substantial energy recovery thus minimizing the total steam consumption required at the urea plant battery limits. The vapours leaving the top of the MP decomposer are partially condensed in a vacuum pre-concentrator where the urea solution leaving the LP decomposer is concentrated upto about 84% before entering the first vacuum evaporator. This results in saving 200 kg/t of 4.5 bar steam and 10 m^3 of cooling water/MT of urea (t = 10°C).

4.3 Case study

Some of the important energy conservation measures implemented in the recent past by some of the fertilizer plants (refer table 16 for plant names) are listed in **Table 18.**

Table 18. Major Energy Saving Schemes Recently Implemented

Measures adopted	Energy saving (Gcal/MT ammonia)
Change of reformer tubes, change of syn. converter internals, change of all catalysts	0.4
Selective oxidation CO at LT outlet by Selectexo process	0.29
Replacement of axial flow syn. converter with radial flow converter	0.29
Change of converter internals from axial flow to radial-axial flow	0.25
Additional air heater to bring down the flue gas temperature from 180°C to 165°C	0.02
Installation of O_2 and CO analysers	0.15

CHAPTER 5

Environmental aspects

One of the major developments in the industrial revolution of India has been the construction and operation od several fertilizer manufacturing facilities producing a variety of nitrogenous and phosphatic fertilizers. The phenomenal growth of Indian fertilizer industry and large volumes of production levels have imposed a great deal of responsibility on the industry to ensure that the environment is protected from the release of undesirable products and chemicals. Fertilizer plants have been taking significant and positive steps to control and minimise the release the pollutants. An overview of fertilizer industry with regard to pollutants emission standards and an assessment of environmental impact is presented in this chapter.

5.1 Generation of pollutants

During the manufacture of fertilisers, various pollutants are generated and released in the liquid effluent, gaseous emissions and solid wastes. The origin of pollutants are usually due to raw material, intermediate product, product, chemical used in the process, side reaction in process, cooling water blowdown, boiler blowdown, demineralisation plant regeneration and raw water and effluent treatment system.

5.1.1 Ammonia plant

5.1.1.1 Partial oxidation process

In this process, the carbon of hydrocarbon feedstock is not completely conbusted, generating unburnt carbon as soot. In most of the plants, provisions are incorporated for recycle of 80% of the carbon generated. The rest of 20% of carbon produced is required to be disposed off. Further, cyanides are formed due to side reaction during gasification. Both carbon and cyanide come out in the wash water. Inplant system is usually provided for removal of major quantity of cyanide in stripper where the stripping is done by steam and acidic gases. However, a part of the stripper bottom effluent containing some residual cyanide is continuously discharged. In case of fuel oil feedstock, the effluent discharged contains suspended carbon, sulphide, formate, ammonia and metals like vanadium, nickel, iron, etc. alongwith cyanide. Where the fuel oil feedstock contains high sulphur (e.g. HSHS containing sulphur 3-4%), sulphur recovery plant is incorporated for recovery of sulphur. In case feedstock is coal, considerable quantity of flyash is discharged in the

wash water of the gasification section. This wash water contains small quantity of cyanide also.

5.1.1.2 Steam reforming process

In the steam reforming process, excess steam than stoichimetric requirements is supplied in the primary reformer. When the gas is cooled, the excess steam condenses out and forms process condensate. The process condensate thus generated contains ammonia, methanol and some organics. In the modern plants, built-in system is provided for removal of major quantity of ammonia by stripping. This makes the condensate fit for use as boiler feed water with or without polishing. However, when the contaminants in the condensate are high, the condensate is unfit for use as boiler feed water and is discharged as effluent.

5.1.1.3 CO_2 recovery

In the CO_2 recovery section, though the absorption towers are operated in closed circuit, some absorbent chemical find their way out in the cooler condensate, sludge formed in the process, leakage and spillage from the system. The type of pollutant depends on the absorbent used.

5.1.1.4 Pumps and compressors

Oil bearing effluent originates from pump and compressor section.

5.1.1.5 Emission

Flue gas from heaters are discharged from the stack. Purge gas from ammonia synthesis section is burnt in the steam reformers of the ammonia plants.

5.1.2 Urea plant

5.1.2.1 Vacuum condensate

Urea solution formed remains associated with ammonium carbamate, ammonium carbonate, ammonia and carbon dioxide. After recovery of ammonia and carbon dioxide, this solution is concentrated in vacuum concentrators. During evaporation, vapours condense to form contaminated condensate. This condensate contains urea, ammonia and carbon dioxide. This is the main source of pollution from the urea plant. In the modern urea plants built-in facility - thermal urea hydrolyser stripper is provided whereby major quantity of contaminants like urea and ammonia are removed from the condensate and recycled in the process. This system appreciably improves the quantity of the condensate.

5.1.2.2 CO_2 compression

Another effluent steam generates from carbon dioxide compression section which mainly contains oil. The ammonia and carbamate solution plunger pump leakage also forms an effluent stream which contains ammonia, urea and oil.

5.1.2.3 Emission

The inert gases are discharged after recovery of ammonia by condensation.

5.1.2.4 Urea dust

Significant quantity of urea dust is discharged from the prilling tower. Generally induced draft prilling towers generate higher quantity of dust than the natural draft towers. Therefore, modern trend is towards installation of natural draft towers. Urea dust also originates from urea silo and bagging plant.

5.1.2.5 Solid waste

Solid urea spillage takes place in and around prilling tower.

5.2 Emission standards

The Central Pollution Control Board (CPCB) has developed following Minimal National standards (MINAS) (**Table 19**) for the straight nitrogenous fertilizer industry, excluding the Calcium Ammonium Nitrate (CAN) and Ammonium Nitrate (AN) plants. These standards are for liquid effluents, particulate matter emissions and Waste water generation from the plant site.

Table 19. NIMAS for straight Nitrogenous fertilizers

S. No.	Parameter	Concentration not to exceed mg/l (except for pH): Plants commissioned Jan 01, 1982 onwards	Plants commissioned prior to Jan 01, 1982
1.	Liquid effluent		
	pH	6.5-8.0	6.5-8.0
	Ammonical Nitrogen	50	75
	Total Kjeldahl Nitrogen	100	150
	Free Ammonical Nitrogen	4	4
	Nitrate Nitrogen	10	10
	Cynide as CN	0.2	0.2
	Vanadium an V	0.2	0.2
	Arsenic as As	0.2	0.2
	Suspended solids	100	100
	Oil and Greese	10	10
	Hexavalent Chromium as Cr	0.1	0.1
	Total Chromium as Cr	2	2
2.	Particulate matter emission (urea)	0.5 kg/t product	2.0 kg/t product
3.	Waste water generation	5 m^3/t of urea or equivalent produced	

5.3 Environmental status

As per another study conducted by the CPCB (report published in July 1994), a total of 8 plants (7.3%) in the fertilizer industry were not complying with the standards set before 1981. Out of these 8 plants, 5 plants were Central Public sector units, 1 plant was state public sector unit and 2 plants were private sector units. All the plants falling under cooperative sector units were found complying with the standards. The status improved significantly since then and as on June 30, 1994 all the plants were found complying with these standards.

The pollutant load in kilogram per tonne of urea produced in the entire sector is given in **Table 20,** which shows continuous reduction in the pollutant load during the past 4 years. The average discharge of various pollutants per year from nitrogenous fertilizers plants is given in **Table 21.** These pollutants were released during the production of around 6.1 million tonnes of Nitrogenous fertilizer.

Table 20. Yearly pollutant load from ammonia-urea production

Pollutants	1988-89	1989-90	1990-91	1991-92
Liquid effluent				
Total nitrogen kg/t urea expressed an ammonia	1.36	0.82	0.75	0.61
Total Chromium mg/t urea	562.00	439.00	360.00	179.00
Air emission				
Urea dust kg/t urea expressed as ammonia	0.56	0.56	0.56	0.56

Table 21. Average pollutant load from Ammonia-urea production in India

Sl. No.	Pollutants	4 year average load (Tonnes/year)
1.	Liquid effluents	
	Total Kjeldahl Nitrogen	9050.0
	Total Chromium	4.8
2.	Air emission	
	Urea dust	6960.0
3.	Solid waste	
	Catalyst	2560.0
	Chromium sludge	85.0
	Arsenic sludge	19.5
	Carbon	34000.0

The urea plant as a whole released about 9 kg ammonia per tonne of urea produced, to the environment during 1991-92 of which about 7.8 kg ammonia is released as emission from various vent, atmospheric absorber, leakage, final product, prilling tower, etc. and the remaining 1.2 kg ammonia is released in liquid effluent discharged from the plant and as urea dust from prilling tower. While several plants older than 20 years continue to operate with obsolete technology and few low operating sick units, India has kept pace with the technological advancements elsewhere in the world. The latest plants in India are comparable with the best in the world. The total ammonia emission from 7 new urea plants commissioned after 1984 is about 5 kg per tonne of urea, of which about 0.2 kg ammonia is released in liquid effluent discharged from the plant and as urea dust from prilling tower. Although the amount of ammonia released depends on many factors such as process, engineering, proper operation and maintenance of the plant, etc., there is considerable scope for reducing ammonia loss especially in old plants.

5.4 Abatement of pollution

The approaches that are generally followed in abatement of pollution are:

1. Incorporation of important pollution control system
2. End of process treatment for removal of pollutants from effluents
3. Recovery, reuse and recycle in the process
4. House keeping

The following points are specifically applicable for ammonia-urea fertiliser plants for their overall environmental status improvement.

- Carbon recycle system shall be made operational. Cyanide stripping system shall be operated always to control cyanide discharge in the effluent.
- Oily effluents of ammonia plant shall be segregated and inplant interceptors shall be provided.
- Process condensate shall be stripped for ammonia removal and reused.
- Vetrocoke system for carbon dioxide recovery shall preferably be changed in favour of non-arsenic system. In case, it is not feasible to change, then discharge of arsenical effluent shall be avoided by incorporating elaborate treatment facility.
- Urea plant shall be provided with adequate capacity captive plants for storing reactor and loop drainings. The capacity shall be sufficient to hold two consecutive drainings. Facility is also needed for reuse of these liquors.
- For the treatment of vacuum condensate, thermal urea hydrolyser stripper shall be provided with suitable facility to reuse the ammonia obtained. Alternatively, vacuum condensate recycle system via cooling tower may be installed. Industry shall make it certain that the vacuum condensate is adequately treated for removal of both ammonia and urea in a well organised system.
- Spillage urea shall be dissolved using urea bearing effluent and recycled in the process. Therefore proper segregation and collection of the effluents shall be made.
- In case of oily effluent of urea plant, segregation shall be practised and suitable oil interceptors shall be incorporated.
- Ammonium salt plants shall adopt appropriate recycle system.

CHAPTER 6

Conclusions

Fertilizers (ammonia-urea) is one of the industrial sectors chosen for detailed analysis under phase - I of the Energy Efficiency Support Project. The study of the sector shows that production of nitrogenous fertilizers is several times more energy intensive than production of any other type of fertilizers. Further, about 81.3% nitrogen production in the year 1992-93 was through urea, justifying the need to direct efforts to ammonia-urea sector of the industry. The industry is highly energy intensive and polluting in nature. It is the single largest consumer of petroleum products which are utilised as feedstock and energy purposes. The total energy consumption for 14.24 million tonnes of urea production in 1994-95 was 11.235 x 10^7 Gcal, which is equivalent to about 10.64 million tonnes of naphtha. Any efforts to conserve energy in the sector, therefore, would result not only in huge monetary savings but also in social benefits by controlling pollution. Keeping in view the number of energy saving opportunities present, the scope for energy conservation and the ability of the sector to participate in the energy conservation programme, the sector is highly recommended to be taken up for the phase - II of the project. Some of the units which can be considered for carrying out energy and environment audits are listed in Annexure I. Some of the organisations working closely with the industry in promotion of energy efficiency and technology upgradation is given in Annexure II.

Plants for energy and environment audit studies

S.No.	Address	Contact person	Tel.	Fax
1.	Nagarjuna Fertilizers & Chemicals Ltd. Nagarjuna Road Kakinada - 533 003 Andhra Pradesh *Registered office* Nagarjuna Hills Hyderabad - 500 482 *Installed capacity* Ammonia plant : 900 MTPD Urea plant : 1500 MTPD	Mr P R Menon, Director (Technical) Mr G M Koorse, General Manager (Operations)	72311	0884-72084
2.	Sriram Fertilizers & Chemicals Sriram Nagar Kota (Rajasthan) *Registered office* 5th Floor, Kanchenjunga Building 18 Barakhamba Road New Delhi - 110 001 *Installed capacity* Ammonia plant : 600 TPD Urea plant : 1000 TPD	Mr S K Agrawal, Sr. Vice President Mr Y K Agarwal, Vice President Mr S K Agrawal, Chief General Manager	(0744)233 91-23398	0744-23296
3.	Krishak Bharti Cooperative Ltd. (KRIBHCO) Hazira plant P.O. Kribhco Nagar Surat - 394 515 Gujarat	Mr T. Rengarajan, Sr. General Manager Mr K. Das, Jt. General Manager (Technical)	620034	620038
	Registered office 49-50, Red Rose Nehru Place New Delhi - 110 019 *Installed capacity* Ammonia plant : 1350 TPD Urea plant : 1100 TPD		6414198	011-6432063

4.	National Fertilizers Ltd. (NFL) Gohana Road Panipat - 132 106 Haryana *Corporate office* Scope complex, Core-III 7 Institutional Area Lodi Road New Delhi - 110 003 *Installed capacity* Ammonia plant : 2,97,000 TPA Urea plant : 5,11,500 TPA	Mr S. C. Kashyap, Dy. General Manager (I/C) Mr A. C. Saini, Dy. General Manager (Works)	20481	01742-45515
5.	National Fertilizers Ltd. (NFL) Naya Nangal Distt. Ropar Punjab - 140 126 *Corporate office* Scope complex, Core-III 7 Institutional Area Lodi Road New Delhi - 110 003 *Installed capacity* Ammonia plant : 900 TPD Urea plant : 1000 TPD	Mr R. S. Sindhwani, Executive Director Mr S. K. Mehta, Dy. General Manager	01881-20533	01887-20541
6.	Indian Farmers Fertiliser Cooperative Ltd. (IFFCO) Unit: Phulpur P.O. Ghiyanagar Distt. Allahabad U. P. - 212 404 *Delhi office* 34, Nehru Place New Delhi - 110 019 *Installed capacity* Ammonia plant : 900 TPD Urea plant : 1500 TPD	Mr D. K. Bhatt, General Manager Mr. Subhash Chandra, Chief Manager (Technical)	641935 6432507	0532-852253 011-6463833

7.	Gujarat State Fertilizer Co. Ltd. (GSFC) P.O. Fertilisernagar - 391750 Distt. Vadodara *Installed capacity* Ammonia plant (2 nos.) : 960 TPD Urea plant (2 nos.) : 1123 TPD	Mr B. D. Rehani, General Manager (Fertiliser) Mr P. A. Dave, Dy. General Manager	372451	0265- 372966
8.	Mangalore Chemicals & Fertilisers Ltd. Panabur Mangalore - 575 010 *Registered office* Khivraj Mansion 10/2, Kasturba Road Bangalore - 560 001 *Installed capacity* Ammonia : 2,17,800 TPA Urea : 3,39,900 TPA	Mr C. N. Satyanarayanan, Sr. Vice President (Works) Mr C. N. Sathyanarayanan, Dy. M. D. (Works) Mr T. K. Bhat, General Manager (Operations)	407601 211691	0832- 407938 217205
9.	Chand Chhap Fertilisers and Chemicals Ltd. Panki Fertiliser Works Post Box no. 7, Udyognagar Kanpur - 208022 *Registered office* Site no. 1, Panki Industrial Area P.O. Udyognagar Kanpur - 208022 U. P. *Installed capacity* Ammonia plant : 4,11,000 TPA Urea : 6,75,000 TPA	Mr M. C. Garg, Vice President (Works) Mr T. N. Mehrotra, Operations Manager	211281	211268
10.	Madras Fertilisers Ltd. Post Bag no. 2 Manali Madras - 600 068 Tamil Nadu *Installed capacity* Ammonia plant : 2,47,500 TPA Urea plant : 2,92,050 TPA	Mr Jacob Eapen, General Manager - Plant & Projects	541001, 541201	541010

11.	Indian Farmers Fertiliser Cooperative Ltd. (IFFCO) Unit: Kalol P.O. Kasturinagar Distt. Gandhinagar - 382 423 Gujarat	Mr V. K. Grover, G. M. Mr A.M. Kunjanny, Jt. General Manager	3256/58	2764-2572
	Delhi office 34, Nehru Place New Delhi - 110 019		6432507	011-6463833
	Installed capacity Ammonia plant : 910 TPD Urea plant : 1200 TPD			
12.	Gujarat Narmada Valley Fertilisers Co. Ltd. P.O. Narmadanagar - 392 015 Distt. Bharuch Gujarat	Mr G. Subba Rao, Managing Director Mr Z. S. Sadliwala, General Manager	(02642) 32001	02642-31595
	Installed capacity Ammonia plant : 1350 TPD Urea plant : 1800 TPD			
13.	Indo Gulf Fertlisers & Chemicals Corpn. Ltd. P.O. Jagdishpur Industrial Area Distt. Sultanpur - 227 817 U. P.	Mr N. K. S. Mahapatra, Sr. Vice President Mr Anand Bihari, Vice President (Technical)		
	Registered office 14-A/5, Park Road Lucknow - 226 001 U. P.			
14.	Indian Farmers Fertiliser Cooperative Ltd. (IFFCO) Unit: Aonla P.O. IFFCO Township Distt. Bareilly U. P.	Mr Suresh Wadhwa, Chief Manager		
	Delhi office 34, Nehru Place New Delhi - 110 019		6432507	011-6463833

15.	Zuari Agro Chemicals Ltd. Jai Kissan Bhawan Zuarinagar - 403 726 *Delhi office* 505 Surya Kiran 19 Kasturba Gandhi Marg New Delhi - 110 001	Mr B. K. Kinekar, Regional Manager Mr P. A. Kamat, Manager

List of organisations

S.No.	Address	Contact person	Tel.	Fax
1.	The Fertiliser Association of India 10. Shaheed Jit Singh Marg, New Delhi - 110 067	Dr S. Nand	667183, 667305	
2.	Projects and Development India Ltd. P. B. No. 125, A-14, Sector 1, Noida - 201 301	Mr A. K. Bhaduri Senior General Manager		
3.	The Fertilizers & Chemicals Travancore Ltd. Eloor, Udyogamandal - 683 501 Cochin, Kerala		85-6101	048485-8125

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